

Activities at OAB (Italy) for the Con-X/HXT optics development: status report

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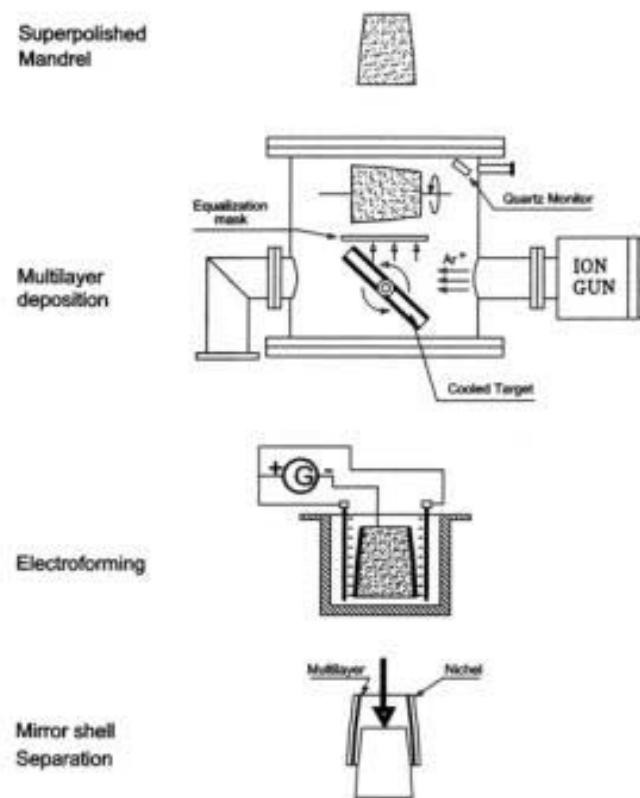
Con-X/FST Meeting - 15-16 Nov 2001

We are exploring how to up-grade of the Ni electroforming replication method (used for making e.g. the Au coated XMM mirrors) to produce the Con-X/HXT optics. This approach can guarantee very good imaging performances.

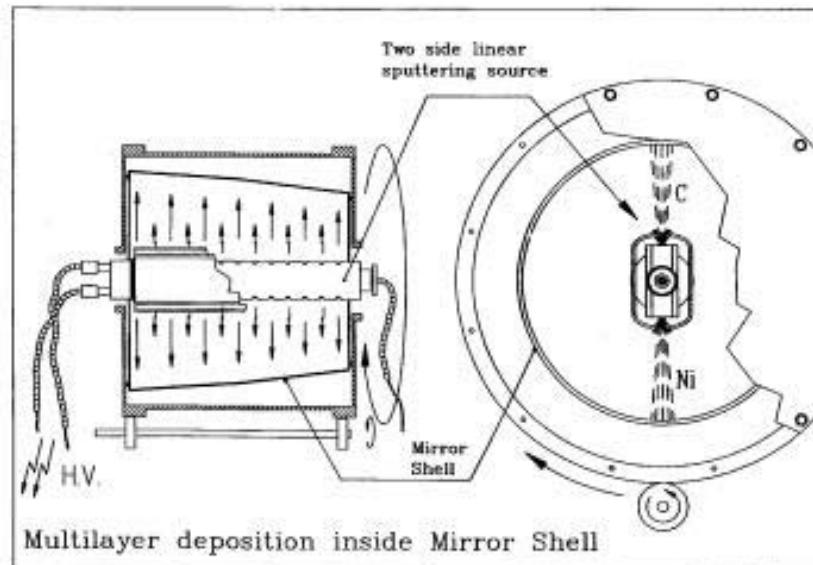
Outline:

- review of the work carried out until now and report on the main achieved results;
- HXT mass requirement: how to meet it with the Ni electroforming replication approach;
- UV test on a thin (0.13 mm) JET-X shell;
- ML vs. single layers telescopes: theoretical effective areas, diameters & flux sensitivities;
- future plans.

Multilayer mirror shell by Ni electroforming replication: 2 different realization approaches (both under investigation at OAB)

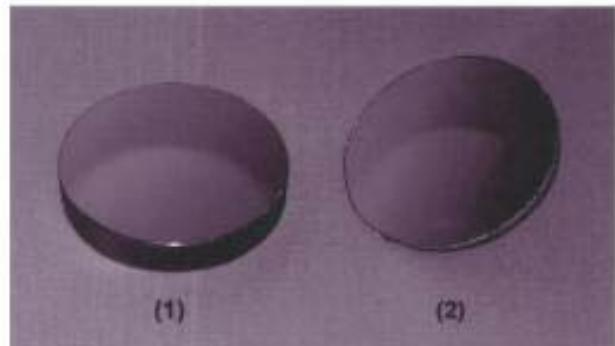


A) “direct” replication of the multilayer film

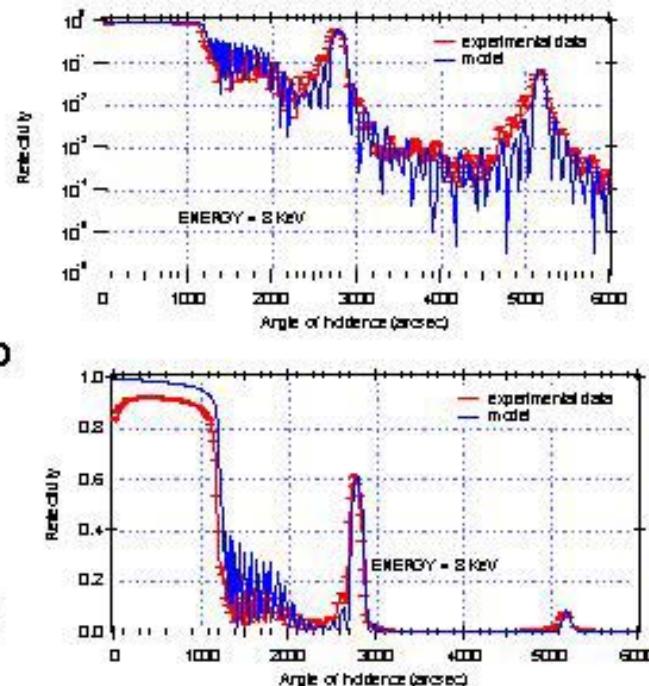
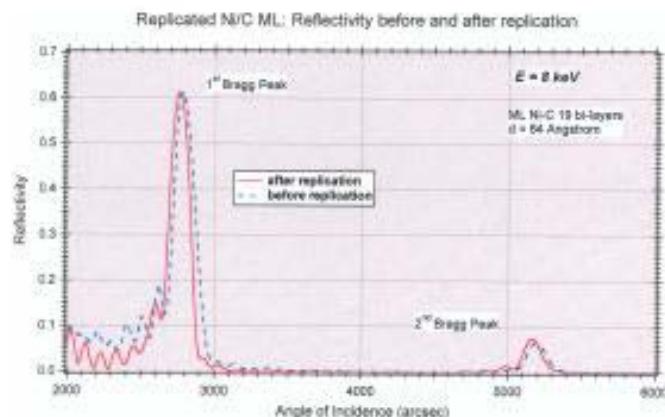


B) deposition of the multilayer film onto the internal surface of a replicated mirror shell (activity carried out in collaboration with the Harvard-Smithsonian CfA)

Production of flat multilayer mirrors by direct Ni electroforming replication (COMPLETELY REPRESENTATIVE)



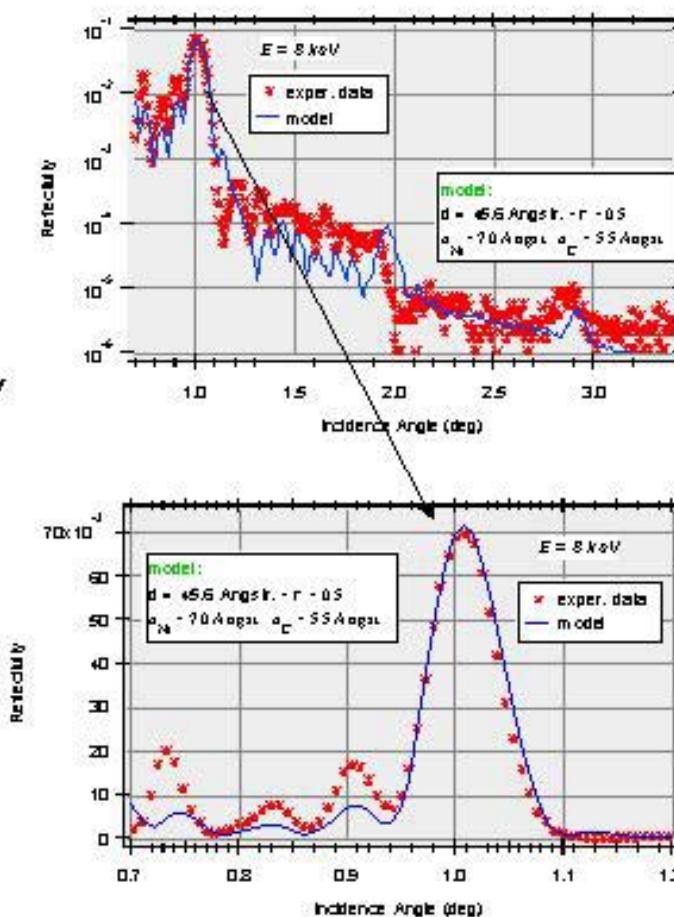
- Flat Mandrel (diam. = 100 mm) superpolished to a roughn. level of 2 Angstr. rms;
- ML Ni/C (21 bilayers) successfully deposited and replicated;
- The reflectivity profile of the replicated side corresponds to that measured before replication;



- the reflectivity profile can be fitted with a model involving a D-W roughness of 4 Angstr.

Realization by direct replication of a double-cone ML mirror prototype exploiting one mandrel (# 12) from the BeppoSAX series

- the mandrel roughness level was 7 Angstr. rms (while the goal of the technology under development by our group is 2 Angstr. Rms, see next viewgraph);
- a Ni/C ML (11 bilayers) has been successfully deposited and replicated by Ni electroforming;
- the D-W roughn. measured by 8 keV reflectivity tests was 7 Angstr., i.e. corresponding to the mandrel surface.



Superpolishing

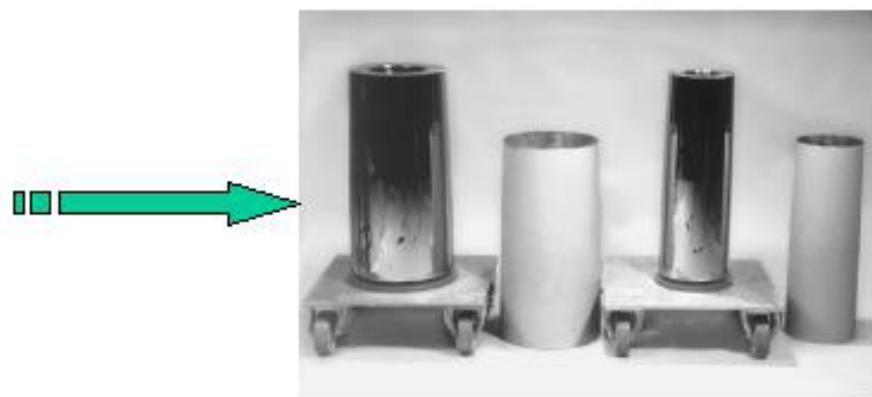
- A crucial point concerning the technique under development is the improvement of the surface quality of the mandrel compared to the soft X-ray mirror with Au coating case.
- A superpolishing machine has been developed at OAB for this specific task
- a first representative single-cone mandrel (height 15 cm, Ø 28 cm) has been successfully superpolished



In the table the roughn. values achieved by the new lapping method on a prototype mandrel surface are compared to those of the SAX mandrel #12

Instrument	Scan Length (μm)	Roughness rms (\AA) SAX #12 mandr.	Roughness rms (\AA) Superpolish. mandr.
WYKO -2.5 X	6000.0	N. A.	10.1
WYKO -20 X	660.0	7.6	3.0
AFM	10.0	6.2	2.4
AFM	1.0	3.4	1.8

Fabrication of a thin (0.13 mm) mirror shell exploiting the largest Wolter-I JET-X mandrel (diam. = 30 cm, height = 60 cm)



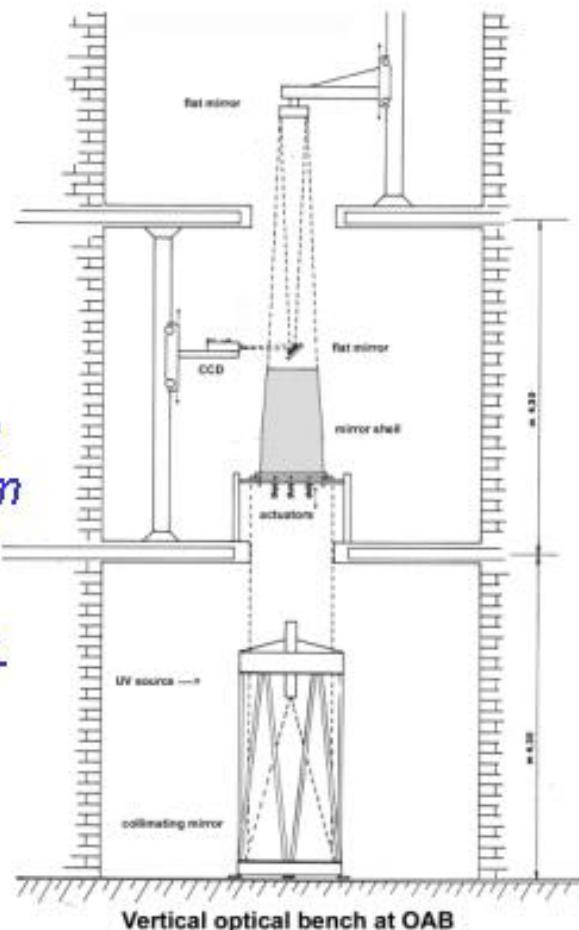
In order to verify the imaging capabilities of thin Ni electroformed mirrors, we realized a 0.13 mm Au coated shell exploiting the largest JET-X mandrel (therefore, the thickness has been diminished of a factor 7.7 compared to the JET-X/SWIFT projects)

Diam = 30 cm

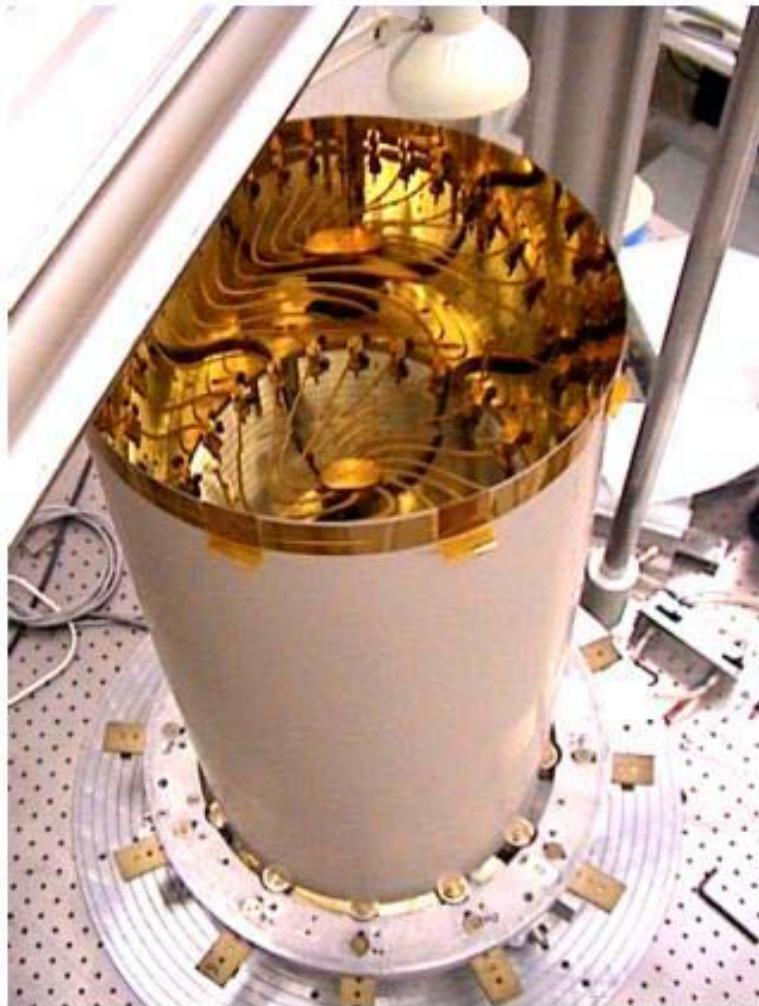
Height = 60 cm

Focal Length = 3.5 m

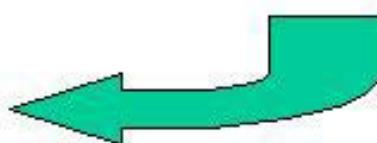
Thickness = 0.13 mm Mirror mass = 660 g



Then performed imaging tests by using the UV vertical optical bench operated at OAB

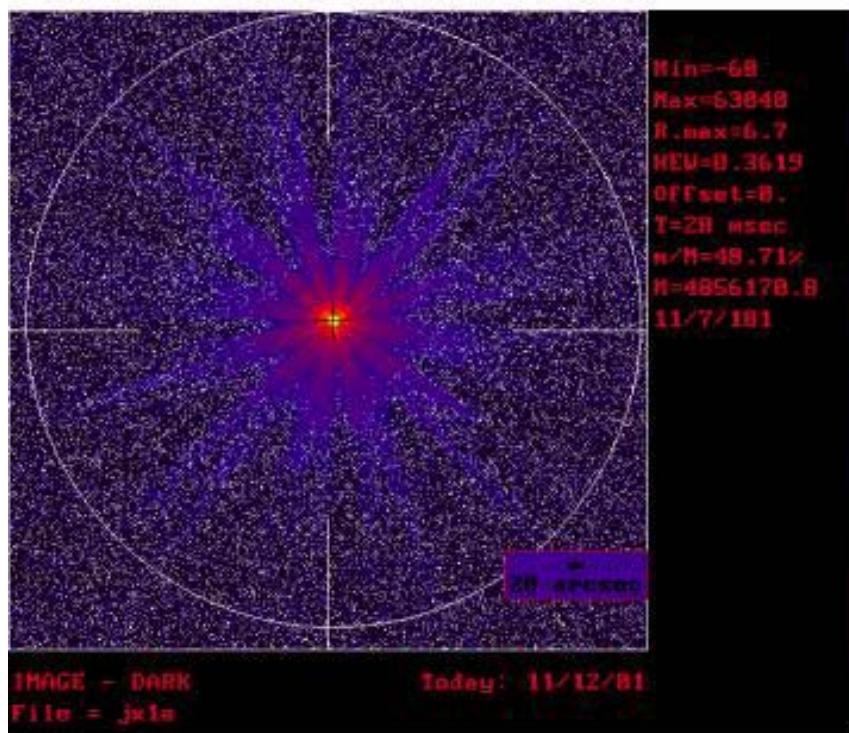


The thin wall mirror shell under measurement by an azimuthal profilometer at OAB

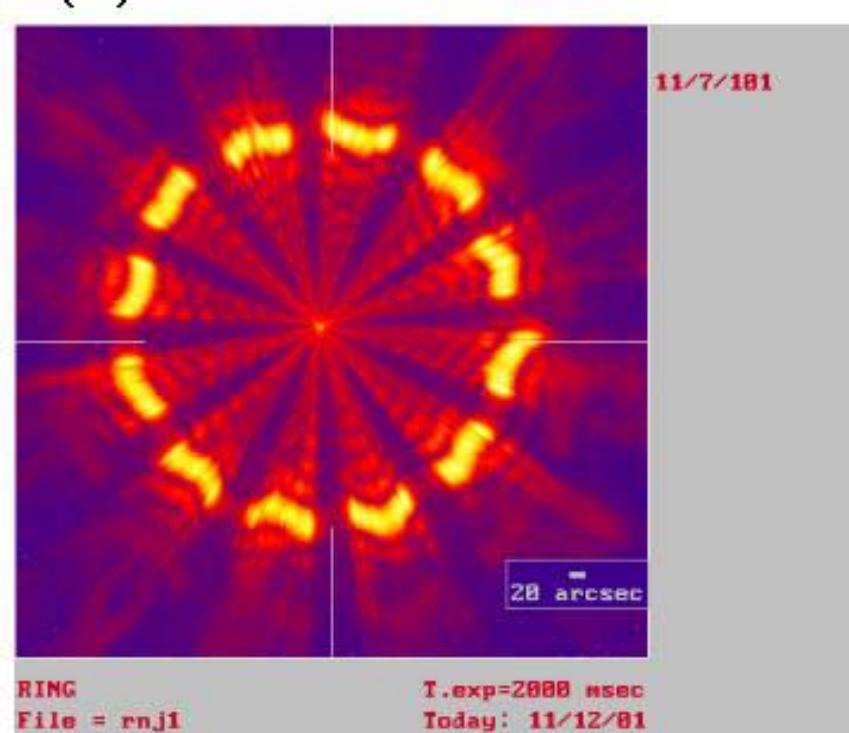


UV images of the focal spot (A) and of the out-of-focus ring (B) concerning the “thin” JET-X shell taken by the vertical optical bench apparatus at OAB

(A)

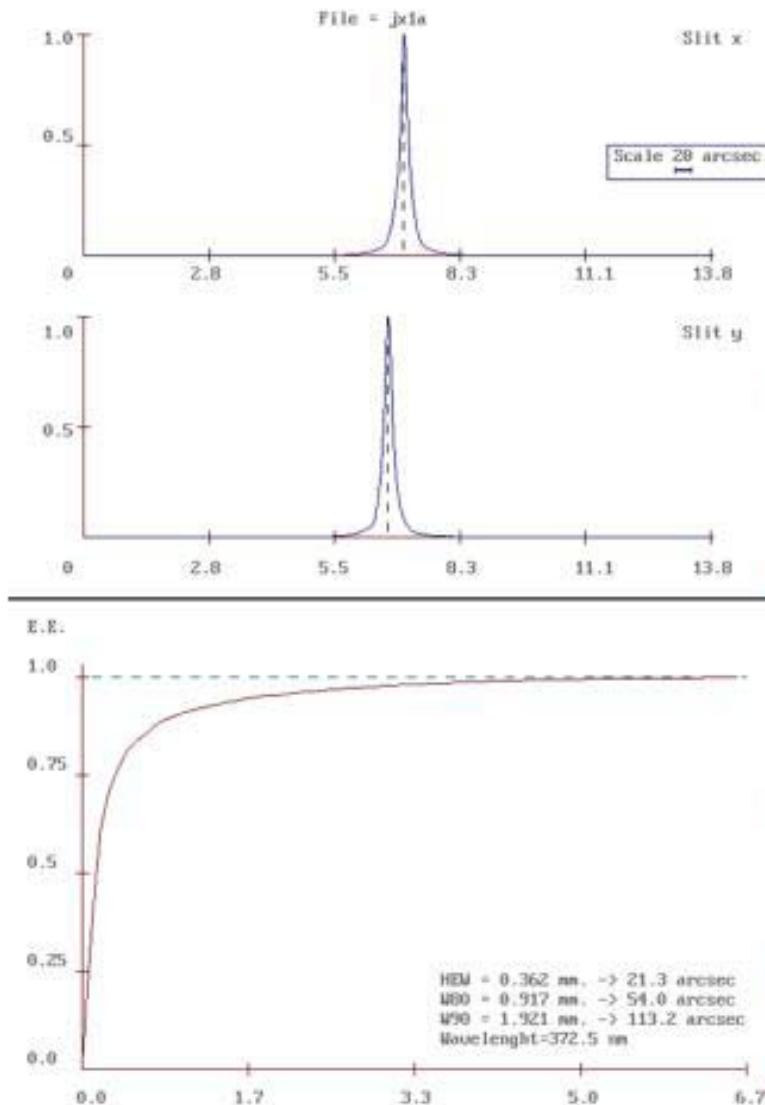


(B)



Note I: the small circle in the figure (A) corresponds to 20 arcsec (diameter);

Note II: the Encircled Energy Function (next viewgraph) has been evaluated including all photons in the largest circle in Fig. (A).

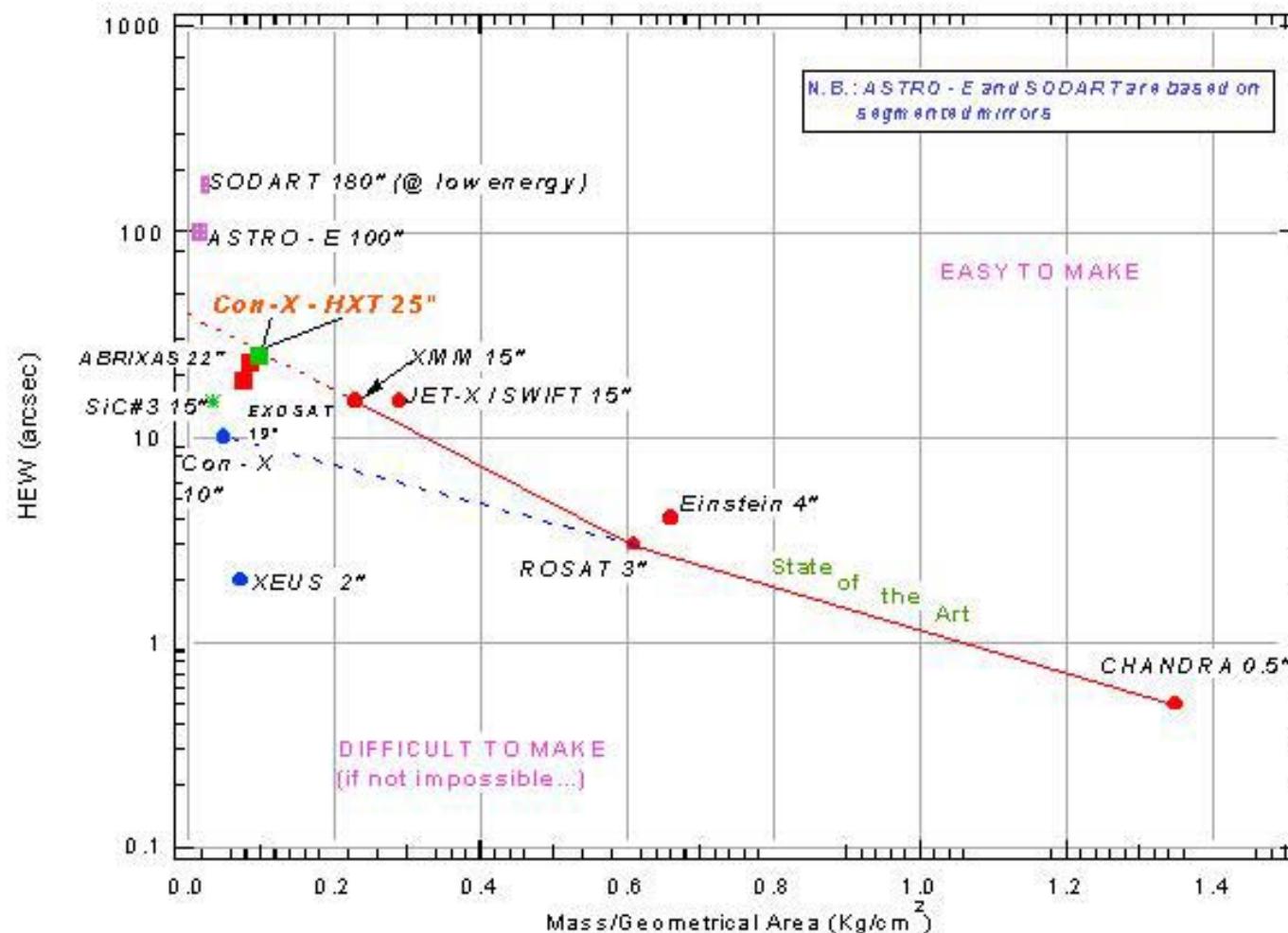


Results from the UV imaging tests

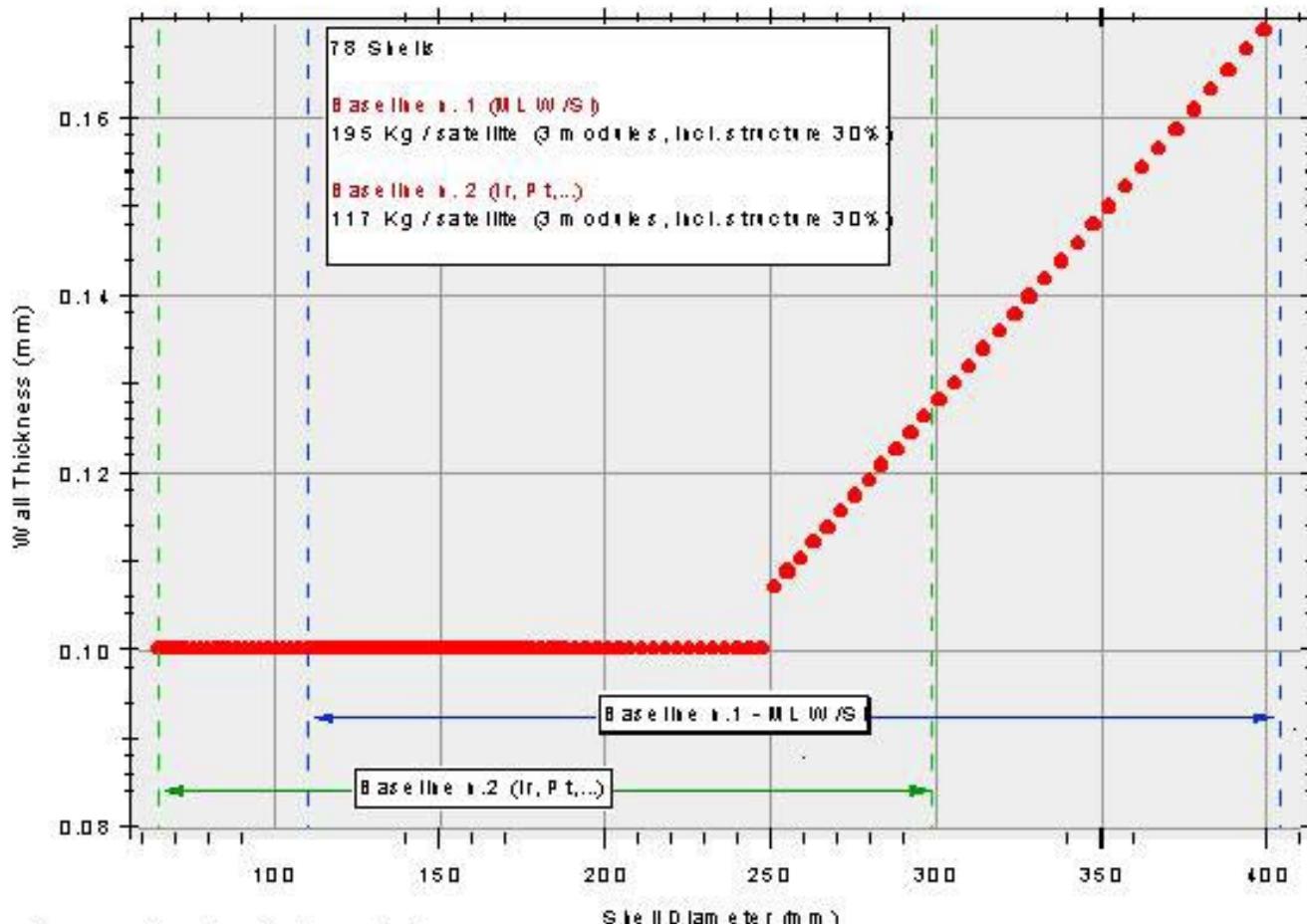
- The HEW derived by the UV images is 21 arcsec;
- The X-ray HEW expected after the deconvolution for the diffraction effect of the UV photons is just **18 arcsec**;
- An estimated HEW value for the complete integrated Con-X/HXT optics after this test is of the order of **25 arcsec**;
- the shell will be tested asap with X-rays (full illumination).

Encircled Energy derived by the UV tests performed on the JET-X thin mirror shell.

HEW vs. Mass/Geometrical_Area ratio expected for Con-X/HXT produced by Ni electroforming replication compared to other X-ray telescopes of the past and of the future

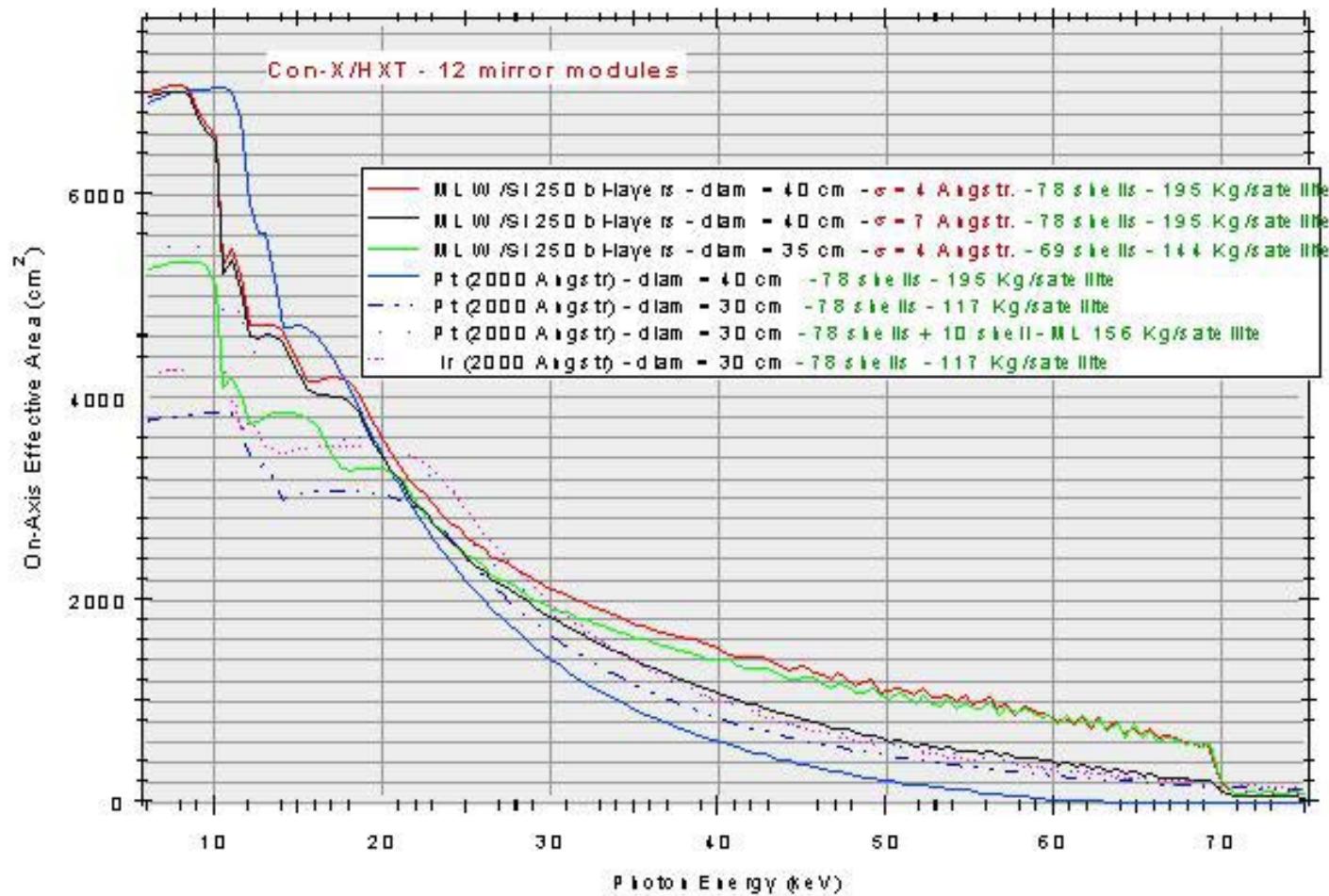


Sequence Thickness vs. Diameter for Con-X/HXT in the case of Wolter I Ni replicated shells

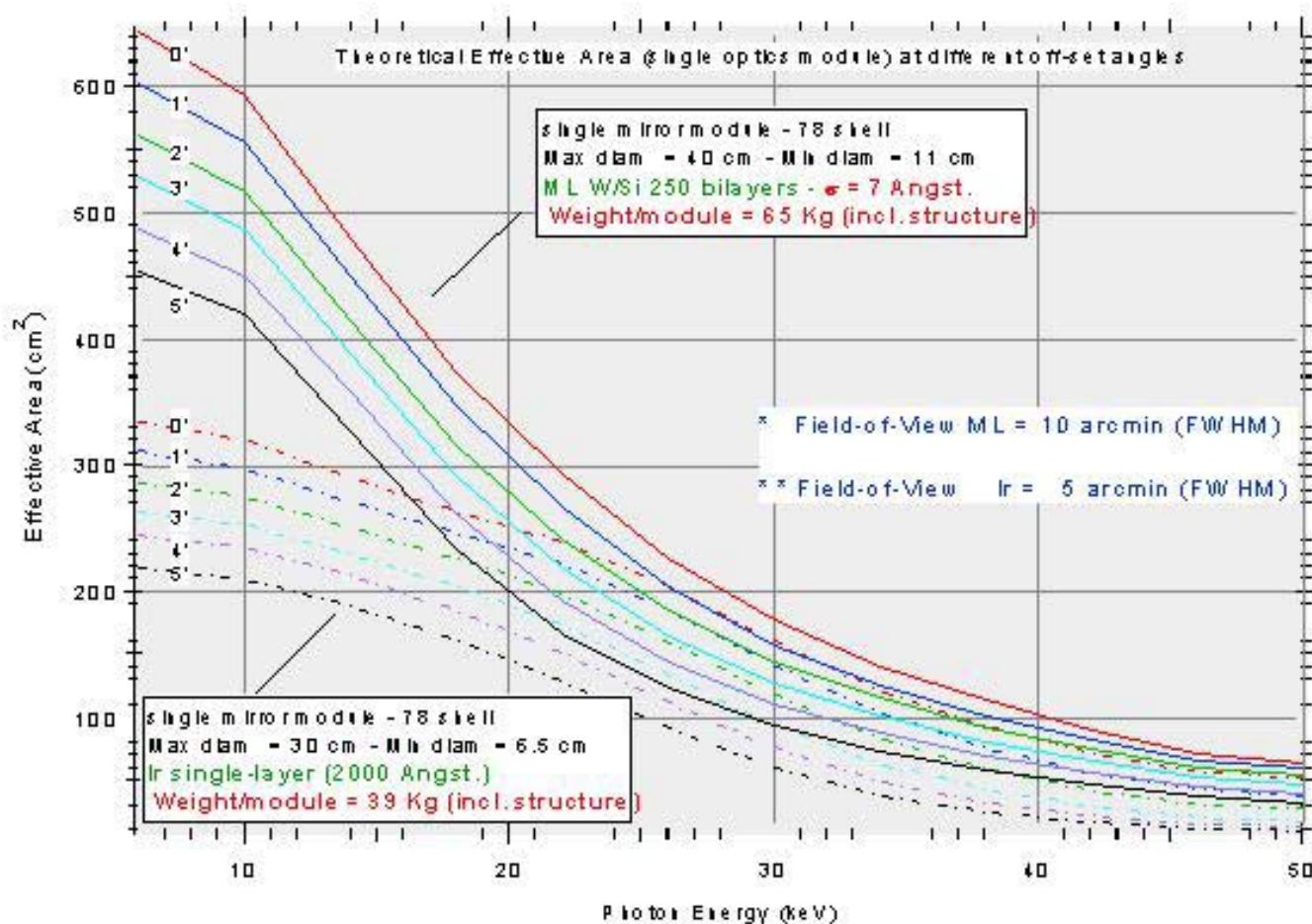


Note: mirror height = 80 cm

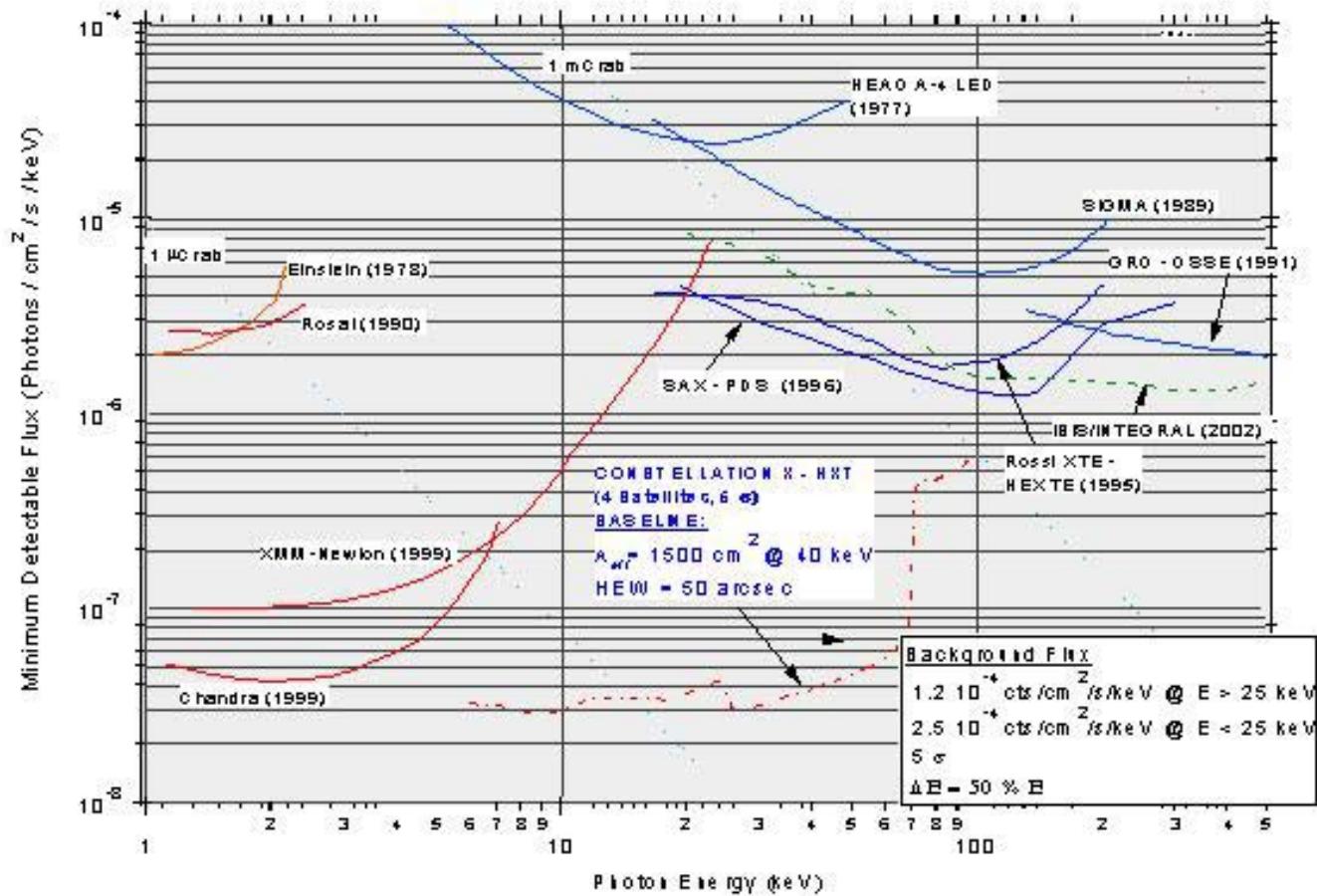
Theoretical on-axis effective areas for Con-X/HXT assuming different configurations based on multilayer supermirrors, single-layer coatings and hybrid solutions.



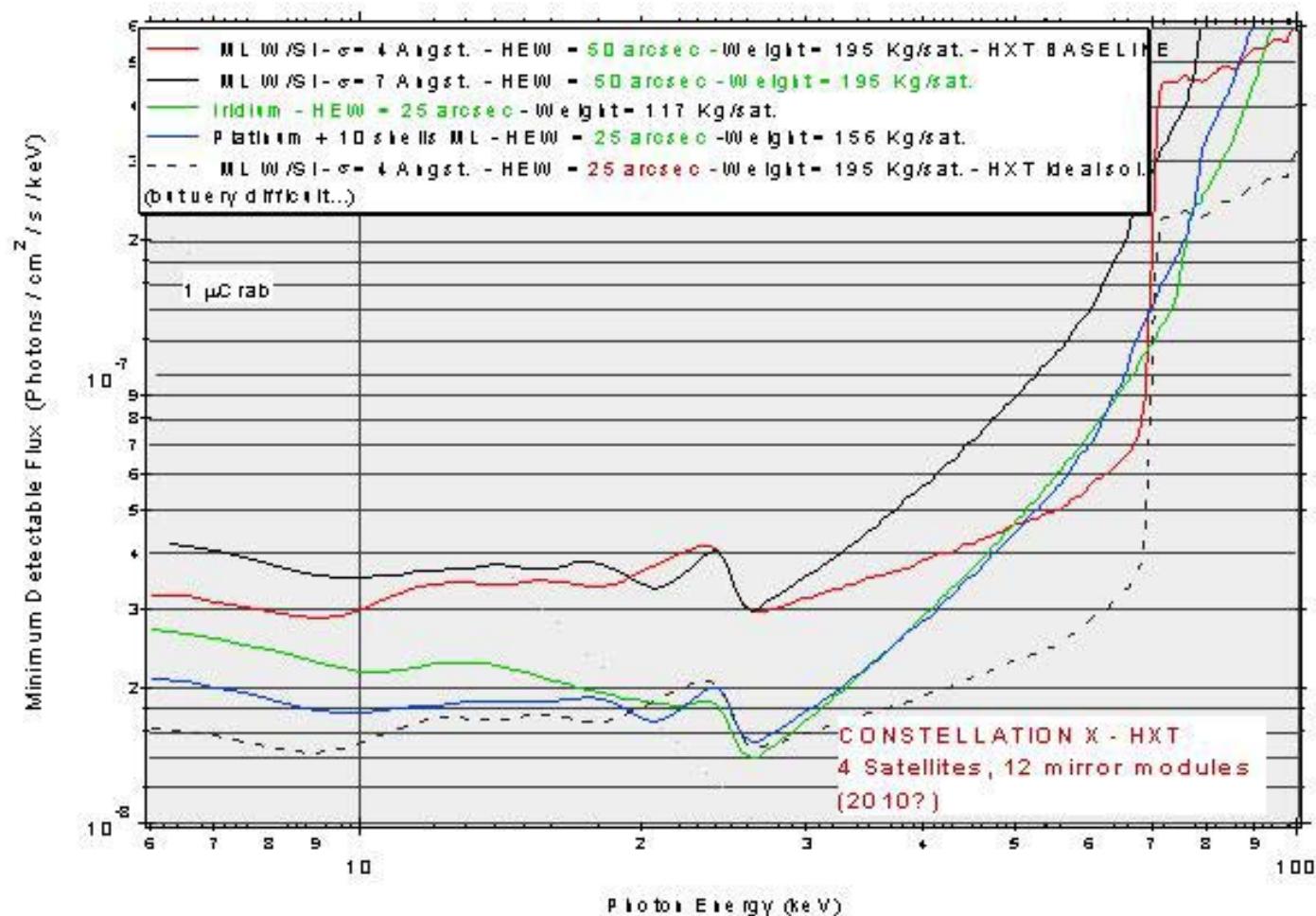
Con-X/HXT Effective Areas at several off-set angles assuming a ML “supermirror” coating (roughn. 7 angstr.) and an Ir single layer coating



Theoretical on-axis flux sensitivity for Con-X/HXT compared to other X-ray missions assuming the present requirement of 1500 cm^2 @ 40 keV and a HEW of 50 arcsec.



Theoretical on-axis flux sensitivity for Con-X/HXT considering Several different possible configurations



Summary:

- in spite of a limited financial support, the results achieved by the OAB group concerning the Con-X/HXT optics production by Ni electroforming replication are very promising;
- the imaging tests performed in UV concerning a thin (0.13 cm) JET-X Wolter-I mirror seem to demonstrate that it is possible to meet the HXT mass requirements still maintaining very good imaging performances. X-ray tests (full illumination) will be also done asap;
- the Ni electroforming approach seems to be a viable way to make the HXT optics assuming as a reflecting surface ML mirrors or a high density material (Ir, Pt,...) single layer either. The possibility of hybrid solutions is also very interesting.